

CLAIMS:

The invention claimed is:

1. A method of forming a reaction product, comprising:

providing a semiconductor substrate comprising a first material;

forming a second material over the first material, the first and second materials being of different compositions and being proximate one another at an interface, the first and second materials as being proximate one another at the interface being capable of reacting with one another at some minimum reaction temperature when in an inert non-plasma atmosphere at a pressure;

providing the interface at a processing temperature which is at least 50°C below the minimum reaction temperature and at the pressure; and

with the interface at the processing temperature and at the pressure, exposing the substrate to a plasma effective to impart a reaction of the first material with the second material to form a reaction product third material of the first and second materials over the first material.

2. The method of claim 1 wherein the first and second materials contact one another at the interface prior to the exposing.

3. The method of claim 1 wherein the first and second materials do not contact one another at the interface prior to the exposing.

4. The method of claim 1 wherein the exposing starts prior to providing the interface at the processing temperature at the pressure.

5. The method of claim 1 wherein the exposing starts after providing the interface at the processing temperature at the pressure.

6. The method of claim 1 wherein the second material is formed to a thickness no greater than 75 Angstroms.

7. The method of claim 6 wherein the second material is formed to a thickness no greater than 25 Angstroms.

8. The method of claim 1 wherein the plasma is inert to reaction with both the first and second materials and inert to deposition of material over the second material.

9. The method of claim 8 wherein the plasma is derived from a gas selected from the group consisting of He, Ar, Ne, Xe, Kr and mixtures thereof.

10. The method of claim 1 wherein the plasma comprises a material which reacts with the second material to form a reaction product fourth material over the reaction product third material.

11. The method of claim 10 wherein the plasma material comprises nitrogen, the first material comprises silicon, the second material comprises elemental titanium, the third material comprises titanium silicide, and the fourth material comprises titanium nitride.

12. The method of claim 10 wherein the plasma material comprises nitrogen, the first material comprises elemental titanium, the second material comprises silicon, the third material comprises titanium silicide, and the fourth material comprises silicon nitride.

13. The method of claim 1 wherein the first and second materials are each conductive.

14. The method of claim 13 wherein the third material is conductive.

15. The method of claim 14 wherein one of the first and second materials comprises titanium and the other of the first and second materials comprises aluminum, the third material comprising  $\text{TiAl}_x$ .

16. The method of claim 13 wherein the third material is insulative.

17. The method of claim 16 wherein one of the first and second materials comprises TiN and the other of the first and second materials comprises B, the third material comprising BN.

18. The method of claim 1 wherein the first and second materials are each insulative.

19. The method of claim 18 wherein the third material is conductive.

20. The method of claim 19 wherein one of the first and second materials comprises carbon and the other of the first and second materials comprises  $\text{SiO}_2$ , the third material comprising  $\text{SiC}$ .

21. The method of claim 18 wherein the third material is insulative.

22. The method of claim 21 wherein one of the first and second materials comprises boron carbide and the other of the first and second materials comprises  $\text{SiO}_2$ , the third material comprising  $\text{B}_2\text{O}_3$ .

23. The method of claim 21 wherein one of the first and second materials comprises boron carbide and the other of the first and second materials comprises  $\text{Si}_3\text{N}_4$ , the third material comprising  $\text{BN}$ .

24. The method of claim 1 wherein one of the first and second materials is insulative and the other of the first and second materials is conductive.

25. The method of claim 24 wherein the third material is conductive.

26. The method of claim 25 wherein one of the first and second materials comprises titanium and the other of the first and second materials comprises  $\text{Si}_3\text{N}_4$ , the third material comprising at least one of TiN or  $\text{TiSi}_x$ .

27. The method of claim 24 wherein the third material is insulative.

28. The method of claim 27 wherein one of the first and second materials comprises  $\text{SiO}_2$  and the other of the first and second materials comprises Ti, the third material comprising  $\text{TiO}_2$ .

29. The method of claim 1 wherein at least one of the first and second materials is semiconductive.

30. The method of claim 29 wherein the third material is conductive.

31. The method of claim 30 wherein the semiconductive material comprises silicon, the other of the first and second materials comprises elemental titanium, and the third material comprising  $\text{TiSi}_x$ .

32. The method of claim 30 wherein the semiconductive material comprises silicon, the other of the first and second materials comprises titanium nitride, and the third material comprising  $\text{TiSi}_x$ .

33. The method of claim 29 wherein the third material is insulative.

34. The method of claim 33 wherein one of the first and second materials comprises Si and the other of the first and second materials comprises RuO<sub>2</sub>, the third material comprising SiO<sub>2</sub>.

35. The method of claim 1 wherein the processing temperature is no greater than 300°C below the minimum reaction temperature.

36. The method of claim 1 wherein the processing temperature is no greater than 100°C below the minimum reaction temperature.

37. The method of claim 1 wherein the processing temperature is no greater than 75°C below the minimum reaction temperature.

38. The method of claim 1 wherein the processing temperature is no greater than 60°C below the minimum reaction temperature.

39. The method of claim 1 wherein the third material is conductive.

40. The method of claim 39 wherein the third material comprises a silicide.

41. The method of claim 40 wherein the exposing is effective to form all conductive metal silicide on the first material to have no more than 10% thickness variation as determined of a thickest portion of said conductive metal silicide formed by the reaction.

42. The method of claim 40 wherein the exposing is effective to form all conductive metal silicide on the first material to have no more than 1% thickness variation as determined of a thickest portion of said conductive metal silicide formed by the reaction.

43. The method of claim 40 wherein the exposing is effective to form all conductive metal silicide on the first material to have from 1% to 3% thickness variation as determined of a thickest portion of said conductive metal silicide formed by the reaction.

44. The method of claim 39 wherein the third material comprises  $\text{TiAl}_x$ .

45. The method of claim 1 wherein the third material is insulative.

46. The method of claim 1 wherein the plasma during the exposing has a plasma density from  $1 \times 10^{11}$  ions/cm<sup>3</sup> to  $1 \times 10^{13}$  ions/cm<sup>3</sup>.

47. The method of claim 1 wherein the exposing comprises a substrate bias.

48. The method of claim 1 wherein the plasma comprises plasma immersion ion implantation.

49. The method of claim 1 wherein the exposing is void of ion implantation.

50. The method of claim 1 being void of ion implantation at the interface.



51. A method of forming a reaction product, comprising:

providing a semiconductor substrate comprising a first material;

forming a second material on the first material, the first and second materials being of different compositions and contacting against one another at an interface, the first and second materials as contacting against one another at the interface being capable of reacting with one another at some minimum reaction temperature when in an inert non-plasma atmosphere at a pressure;

providing the interface at a processing temperature which is at least 50°C below the minimum reaction temperature and at the pressure; and

with the interface at the processing temperature and at the pressure, exposing the substrate to a plasma effective to impart a reaction of the first material with the second material to form a reaction product third material of the first and second materials over the first material, the plasma being inert to reaction with both the first and second materials and inert to deposition of material over the second material.

52. The method of claim 51 wherein the second material is formed to a thickness no greater than 75 Angstroms.

53. The method of claim 52 wherein the second material is formed to a thickness no greater than 25 Angstroms.

54. The method of claim 51 wherein the exposing starts prior to providing the interface at the processing temperature at the pressure.

55. The method of claim 51 wherein the exposing starts after providing the interface at the processing temperature at the pressure.

56. The method of claim 51 wherein the first and second materials are each conductive.

57. The method of claim 56 wherein the third material is conductive.

58. The method of claim 57 wherein one of the first and second materials comprises titanium and the other of the first and second materials comprises aluminum, the third material comprising  $\text{TiAl}_x$ .

59. The method of claim 56 wherein the third material is insulative.

60. The method of claim 59 wherein one of the first and second materials comprises TiN and the other of the first and second materials comprises B, the third material comprising BN.

61. The method of claim 51 wherein the first and second materials are each insulative.

62. The method of claim 61 wherein the third material is conductive.

63. The method of claim 62 wherein one of the first and second materials comprises carbon and the other of the first and second materials comprises  $\text{SiO}_2$ , the third material comprising  $\text{SiC}$ .

64. The method of claim 61 wherein the third material is insulative.

65. The method of claim 64 wherein one of the first and second materials comprises boron carbide and the other of the first and second materials comprises  $\text{SiO}_2$ , the third material comprising  $\text{B}_2\text{O}_3$ .

66. The method of claim 64 wherein one of the first and second materials comprises boron carbide and the other of the first and second materials comprises  $\text{Si}_3\text{N}_4$ , the third material comprising  $\text{BN}$ .

67. The method of claim 51 wherein one of the first and second materials is insulative and the other of the first and second materials is conductive.

68. The method of claim 67 wherein the third material is conductive.

69. The method of claim 68 wherein one of the first and second materials comprises titanium and the other of the first and second materials comprises  $\text{Si}_3\text{N}_4$ , the third material comprising at least one of  $\text{TiN}$  or  $\text{TiSi}_x$ .

70. The method of claim 67 wherein the third material is insulative.

71. The method of claim 70 wherein one of the first and second materials comprises  $\text{SiO}_2$  and the other of the first and second materials comprises Ti, the third material comprising  $\text{TiO}_2$ .

72. The method of claim 51 wherein at least one of the first and second materials is semiconductive.

73. The method of claim 72 wherein the third material is conductive.

74. The method of claim 73 wherein the semiconductive material comprises silicon, the other of the first and second materials comprises titanium, the third material comprising  $\text{TiSi}_x$ .

75. The method of claim 72 wherein the third material is insulative.

76. The method of claim 75 wherein one of the first and second materials comprises Si and the other of the first and second materials comprises  $\text{RuO}_2$ , the third material comprising  $\text{SiO}_2$ .

77. The method of claim 51 wherein the processing temperature is no greater than  $300^\circ\text{C}$  below the minimum reaction temperature.

78. The method of claim 51 wherein the processing temperature is no greater than 100°C below the minimum reaction temperature.

79. The method of claim 51 wherein the processing temperature is no greater than 75°C below the minimum reaction temperature.

80. The method of claim 51 wherein the processing temperature is no greater than 60°C below the minimum reaction temperature.

81. The method of claim 51 wherein the third material is conductive.

82. The method of claim 81 wherein the third material comprises a silicide.

83. The method of claim 81 wherein the third material comprises  $\text{TiAl}_x$ .

84. The method of claim 51 wherein the third material is insulative.

85. The method of claim 51 wherein the plasma during the exposing has a plasma density from  $1 \times 10^{11}$  ions/cm<sup>3</sup> to  $1 \times 10^{13}$  ions/cm<sup>3</sup>.

86. The method of claim 51 wherein the exposing comprises a substrate bias.

87. The method of claim 51 wherein the plasma comprises plasma immersion ion implantation.

88. The method of claim 51 wherein the exposing is void of ion implantation.

89. The method of claim 51 being void of ion implantation at the interface.

90. A method of forming a conductive metal silicide by reaction of metal with silicon, comprising:

providing a semiconductor substrate comprising a first material, the first material comprising silicon in elemental form;

forming a second material over the first material, the second material comprising at least one of an elemental metal or a metal compound rich in metal, the first and second materials being proximate one another at an interface, the first and second materials as being proximate one another at the interface being capable of reacting with one another at some minimum reaction temperature when in an inert non-plasma atmosphere at a pressure to form a metal silicide;

providing the interface at a processing temperature which is at least 50°C below the minimum reaction temperature and at the pressure; and

with the interface at the processing temperature and at the pressure, exposing the substrate to a plasma effective to impart a reaction of the first material with the second material to form a metal silicide on the first material, the plasma being inert to reaction with both the silicon and the at least one of the elemental metal and the metal compound and inert to deposition of material over the second material.

91. The method of claim 90 wherein the second material is formed to a thickness no greater than 75 Angstroms.

92. The method of claim 91 wherein the second material is formed to a thickness no greater than 25 Angstroms.

93. The method of claim 90 wherein the exposing starts prior to providing the interface at the processing temperature at the pressure.

94. The method of claim 90 wherein the exposing starts after providing the interface at the processing temperature at the pressure.

95. The method of claim 90 wherein the second material comprises elemental metal.

96. The method of claim 95 wherein the second material consists essentially of elemental metal.

97. The method of claim 90 wherein the second material comprises a metal compound rich in metal.

98. The method of claim 97 wherein the second material consists essentially of one or more metal compounds rich in metal.

99. The method of claim 90 wherein the silicon and the at least one of a metal and metal compound contact one another at the interface prior to the exposing.



100. The method of claim 90 wherein the silicon and the at least one of a metal and metal compound do not contact one another at the interface prior to the exposing.

101. The method of claim 90 wherein the plasma is derived from a gas selected from the group consisting of He, Ar, Ne, Xe, Kr and mixtures thereof.

102. The method of claim 90 wherein the processing temperature is no greater than 300°C below the minimum reaction temperature.

103. The method of claim 90 wherein the processing temperature is no greater than 100°C below the minimum reaction temperature.

104. The method of claim 90 wherein the processing temperature is no greater than 75°C below the minimum reaction temperature.

105. The method of claim 90 wherein the processing temperature is no greater than 60°C below the minimum reaction temperature.

106. The method of claim 90 wherein the plasma during the exposing has a plasma density from  $1 \times 10^{11}$  ions/cm<sup>3</sup> to  $1 \times 10^{13}$  ions/cm<sup>3</sup>.

107. The method of claim 90 wherein the exposing comprises a substrate bias.

108. The method of claim 90 wherein the metal silicide formed on the first material has a thickness of from 5 Angstroms to 100 Angstroms.

109. The method of claim 90 wherein the exposing is effective to form all conductive metal silicide on the first material to have no more than 10% thickness variation as determined of a thickest portion of said conductive metal silicide formed by the reaction.

110. The method of claim 90 wherein the exposing is effective to form all conductive metal silicide on the first material to have no more than 1% thickness variation as determined of a thickest portion of said conductive metal silicide formed by the reaction.

111. The method of claim 90 wherein the exposing is effective to form all conductive metal silicide on the first material to have from 1% to 3% thickness variation as determined of a thickest portion of said conductive metal silicide formed by the reaction.

112. The method of claim 90 wherein the plasma comprises plasma immersion ion implantation.

113. The method of claim 90 wherein the exposing is void of ion implantation.

114. The method of claim 90 being void of ion implantation at the interface.